1.0 INTRODUCTION

1.1 Background

The 1992 WARC allocated the 1675-1710 MHz frequency band on a primary basis to the MSS (Earth-to-Space) in Region 2 (i.e., the Americas). In that frequency band, WARC-92 adopted Radio Regulation (RR) No. 735A, which protects the operation and further development of the Meteorological-Satellite (METSAT) and Meteorological Aids (METAIDS) services from the MSS. In order to comply with RR No. 735A, interference from mobile earth stations to current and future meteorological receivers must be below acceptable levels. Interference from meteorological transmitters to MSS satellites must be at acceptable levels in order for the band to be useful for MSS.

1.2 Objective

The objective of this annex is to define acceptable approaches to sharing between domestic MSS and incumbent services in the 1675-1710 MHz band.

1.3 Approach and Overview

The sharing analyses were conducted in two phases. In the first phase, general analyses were conducted in order to identify and initially assess various sharing approaches (Section 2). Usage of the 1675-1710 MHz band in North America was reviewed, and representative parameters of incumbent systems were identified for analysis (Section 2.1); potentially worst-case parameters of MSS systems were identified for analysis (Section 2.2); and potential co-channel and adjacent channel sharing constraints for the prevention of interference to meteorological and MSS systems were calculated (Sections 2.3 and 2.4). These results indicated that sharing approaches based on time or geographic separation (i.e., co-channel sharing) and frequency avoidance (i.e., adjacent channel sharing) may be workable. Because the frequency avoidance approach is easiest to implement, it was further evaluated in a second phase of analyses in which adjacent channel sharing effects were evaluated in greater detail than in the first analysis phase (Section 3). The associated interference mechanisms were identified (Sections 3.1 and 3.2) and a method for quantifying potential "cosite" interference was developed (Section 3.3) and applied (Section 3.4). The overall conclusions from both phases of analysis were summarized (Section 4).

2.0 SHARING WITH INCUMBENT METEOROLOGICAL SYSTEMS

2.1 Band Survey And Definition Of Representative Incumbent Systems

A survey of available literature was conducted in order to identify the services and systems incumbent in the 1675-1710 MHz band. The international and US allocations were reviewed, and the usage of the band was determined from the International Frequency List (IFL), the US Government Master File (GMF), and the non-Government GMF (NGMF). This section presents the results of that effort.

2.1.1 International and US Allocations

Table 1 (at the back of this report) shows the current ITU allocations and relevant footnotes for the 1675-1710 MHz frequency band. The US table of allocations for both government and non-government users is similar to the ITU Region 2 allocations, except that Mobile Satellite (Earth-to-space) is not allocated, non-government fixed in the 1700-1710 MHz band is secondary, and the following additional footnotes are applied:

- US211 - In the bands 1670-1690 MHz ... applicants for airborne or space station assignments are urged to take all practical steps to protect radio astronomy observations in the adjacent bands from harmful interference; however, US74 applies.

- G118 - Government fixed stations may be authorized in the band 1700-1710 MHz only if spectrum is not available in the band 1710-1850 MHz.

It is noteworthy that on September 22, 1992, Motorola Petitioned the FCC to establish Mobile Satellite (Earth-to-space) allocations in the 1675-1710 MHz band. The FCC has not yet placed that Petition on public notice.

2.1.2 Band Usage

A 1981 NTIA Spectrum Resource Assessment (TR-81-80) reports 177 government frequency assignments with 152 of them being radiosondes. A majority (145) of these radiosonde assignments are in the 1670-1680 MHz band. This information was obtained from the 1981 Government Master File (GMF). In the Non-Government Master File (NGMF) there were 13 assignments listed in the 1981 study. The ITU frequency Assignment File lists 132 assignments in the 1670-1710 MHz band according to the 1980 resource assessment; currently, the IFL lists 1300 assignments, which are listed and organized by station type and by country in the Tables 2 and 3, respectively.

Because there are few fixed and mobile assignments in the band in the US and elsewhere in North America, these services will be disregarded.[1] In addition, because

[1] The few stations in the fixed and mobile services could, for example, be reaccommodated in other bands or may be protected in the same manner as meteorological stations.

there are no assignments for earth exploration-satellite service in the US, systems in that service will be considered only as interferers.

2.1.3 Parameters of Representative Systems

Major systems listed in the IFL include radiosondes and geostationary and low-Earth-orbit (LEO) meteorological satellite systems. The METSAT systems include systems in two national weather service programs: TIROS (LEO) and GOES (geostationary), for which representative parameters are listed in Table 4. Current foreign systems include Europe's METEOSAT and Japan's GMS systems using geostationary satellites that are described in Table 5; satellites in these foreign systems may occasionally be moved to serve North America (i.e., to cover for failed GOES satellites). In addition, the parameters of a planned earth exploration-satellite system using the 1675-1710 MHz band (i.e., "SPOT") are shown in Table 5. Representative parameters for radiosondes operating in the METAIDS service are listed in Table 6.

2.1.4 METSAT Evolution and Frequency Plans

Tables 7 and 8 list frequency plans for current and planned US meteorological satellite systems, respectively. The GOES NEXT series will be phased into service starting around 1994/5 (currently overdue as a result of procurement problems). The NOAA OPQ series may not be implemented until around 2005; however, the associated transmission system may be implemented around the turn of the century by the Europeans (EUMETSAT). Table 9 shows the current and future spectrum vacancies based on the frequency plans in Tables 7 and 8.

The apparent future decrease in occupied bandwidth in Table 9 results from moving high capacity links to other bands and the use of more efficient data coding and modulation techniques (e.g., elimination of Manchester coding in NOAA OPQ). However, the generation of space segment following that of Table 8 should be expected to occupy more bandwidth (and use different carrier frequencies), insofar as additional efficiency improvements are unlikely and increased data rates or new downlinks may be needed to accommodate new instruments (e.g., additional sensor channels or higher resolution). Nonetheless, from these data, it is evident that frequency avoidance is feasible on the basis of frequency usage by meteorological systems and that time sharing may be workable at some frequencies.

2.2 MSS System Parameters

The MSS parameters used in the ensuing sharing analyses are adapted from AMSC's MSS narrowband system currently being constructed in the 1530-1559/1626.5-1660.5 MHz bands, as well as an analogous spread spectrum system. The assumed parameters are listed in Table 10. These parameter values reflect the highest potential mobile earth station transmitter power levels that may be used by AMSC, which constitutes a worst-case situation for sharing. Lower mobile earth station transmitter power levels could be used if, for example, higher satellite antenna gain is used in the satellites that implement the 1675-1710 MHz band.

2.3 MSS Interference To Meteorological Systems

2.3.1 Separation Distance Analysis

Tables 12 and 13 provide results for analyses of interference to representative, incumbent, meteorological systems from the assumed MSS narrowband and spread spectrum transmissions, respectively. The analysis method is based on the propagation model in CCIR Report 715 (Propagation by Diffraction) without considering actual terrain and foliage. Separation distances were calculated for co-channel and adjacent channel operation assuming that the mobile earth station antenna provides no discrimination toward the horizon. When assuming the minimum off-axis angles between the meteorological receiver antenna mainbeam and the mobile earth station, the required separation distances between a mobile earth station and a meteorological receiver for co-channel operation with narrowband and spread spectrum MSS emissions were found to be 18 to 45 km and 18 to 31 km, respectively. Increasing the off-axis angle at the meteorological receiver antenna toward the mobile earth station reduces the separation distances to 8 to 37 km for the narrowband MSS system and 8 to 24 km for the spread spectrum MSS system.

The separation distances for adjacent channel sharing with the narrowband MSS system use the mobile earth station carrier and spurious EIRP levels specified on AMSC's FCC Form 493. The adjacent channel interference was assumed to occur only as the result of the spurious emissions of mobile earth stations that fall within the meteorological channel (i.e., as opposed to the more detailed considerations made in Section 3, herein). It was assumed that there is a 4 kHz separation between the MSS carrier and the edge of the meteorological receiver passband as defined by the noise bandwidth. The same off-tuning is assumed in the case of spread spectrum MSS. These assumptions yield the same effective interfering EIRP from the narrowband and spread spectrum systems. The results show that with the stated assumptions, a meteorological receiver must be separated from the mobile earth station by 0 to 17 km in the azimuth yielding the minimum assumed off-axis angles between the meteorological receiving antenna mainbeam and the mobile earth station. By increasing the off-axis angle at the meteorological receiver antenna to 48°, the separation distances are reduced to 0 to 10.4 km. Table 14 summarizes the adjacent channel results and shows the separation distances associated with greater off-tuning of the MSS and meteorological channels such that the MSS transmitter noise floor coincides with the meteorological receiver passband.

2.3.2 Discussion of Results

The low permissible levels of interference for WEFAX (1st rows of Tables 12 and 13); Meteosat SDUS (6th rows); and Meteosat CDA/DATTS (7th rows) result from low link power margins and yield the relatively large separation distances. In the latter case (i.e., a Meteosat spacecraft repositioned to serve the US), NOAA most likely would employ its relatively large CDA antennas (e.g., rows 2) that would yield margins that are larger than have been assumed, and so, higher levels of permissible interference and smaller separation distances would result. The antenna gains and margins assumed for the first two cases are the smallest that are in general use; further research may support assumption of larger margins that would yield smaller separation distances. The adjacent channel sharing results indicate that in order to share the band, the transmitter noise level may result in perceptible interference with small separation distances. Thus, further investigation is needed of the potential interference associated with frequency avoidance approaches to sharing (see Section 3.0).

For a given MSS satellite antenna gain, spread spectrum MSS has no significant advantages over narrowband MSS with respect to co-channel sharing with meteorological receivers. This is because in all cases except for WEFAX (1st rows), the victim receivers have a wide bandwidth. In the case of co-channel sharing with WEFAX, the interfering EIRP in the receiver passband bandwidth is much lower than that of the narrowband system, but Fresnel zone clearance increases on the potentially shorter interfering signal path yield reduced dB/km losses and separation distance is reduced by less than 50%.

Spread spectrum MSS has disadvantages compared to narrowband MSS with respect to adjacent-channel sharing with meteorological receivers. This is because the available frequency gaps between meteorological channels may be too small to accommodate the spread spectrum signal in many cases. In addition, it may be more difficult to reduce the transmitter noise floor sufficiently to enable band sharing (except by frequency assignment by location).

Based on the above findings, Table 15 outlines the general MSS sharing approaches that may be applicable in the 1675-1710 MHz frequency band. These approaches consist of frequency, time, and/or distance separation. The near-term column of approaches pertain to sharing under current conditions such as lack of knowledge of victim receiver sites. The long-term column indicates additional sharing approaches that might be possible based on procedural, design, and operating changes.

2.4 Meteorological System Interference To MSS

2.4.1 C/I Analysis

Tables 16 and 17 present carrier-to-interference (C/I) ratios for interference to narrowband and spread spectrum MSS uplinks, respectively. It was assumed that interference would be at the highest level when the MSS satellite was located to the opposite side of the Earth from a meteorological satellite (antipodal analysis) such that the METSAT satellite antenna mainbeam is directed at the MSS satellite. (Note that US METSATs are more favorably positioned with respect to geostationary MSS satellites that cover the US.) The AMSC satellite antenna gain toward the METSAT satellites and

METAIDS stations were assumed to be 12 dBi and 32 dBi, respectively. The analysis procedure followed ITU-R Document 7C/TEMP/27 (Rev. 1) using the appropriate input parameters.

In order to assess potential MSS transponder loading by meteorological transmissions, a calculation was also made of the total interference power that may be received in the 1675-1710 MHz band. It was assumed that all the meteorological downlinks are operating and 80 radiosondes are simultaneously transmitting with equal EIRP toward the MSS satellite. The received interfering power totaled to -136.5 dBW. This can be compared with a total noise power over a 35 MHz transponder bandwidth of -125.1 dBW (noise temperature = 633 K), which indicates that an insignificant amount of the MSS satellite transponder power could be consumed by interference (i.e., <<1%).

2.4.2 Discussion of Results

The GOES forecast center transmissions are the only meteorological transmissions shown to potentially cause interference to MSS narrowband operation. Assuming that a C/I of 23 dB is readily acceptable (i.e., very small reduction in MSS link power margin), it is shown in Table 16 for narrowband MSS channels that the incumbent services will not cause unacceptable co-channel interference except perhaps for the GOES forecast center link (C/I of 19.9 dB). The latter 19.9 dB C/I will not greatly degrade narrowband MSS operations (less than 1 dB reduction in fade margin) and should be acceptable; in any case, co-channel operation with the narrowband forecast center links is easily avoided. Numerous radiosondes may be in operation simultaneously, such that the C/I would be proportionately lower than the values in Table 16; however, because the frequency of each radiosonde drifts with changes in temperature caused by changes in radiosonde altitude, it is unlikely that many of the radiosondes will simultaneously operate at the same frequency.

For a spread spectrum MSS transmission (Table 17), the C/I ratios range from 33.4 dB to 10.9 dB. Based on an I/N of -5 dB and the available processing gain, the required C/I for acceptable MSS operation is -2 dB for narrowband meteorological links (i.e., bandwidth << 1.25 MHz). All narrowband meteorological links exceed the required C/I ratio. However, the interference from the wideband GMS CDA transmissions may raise the noise floor at the MSS demodulator by about 3 dB over a bandwidth of 20 MHz, which may be unacceptable.

3.0 DETAILED ANALYSIS OF THE FREQUENCY AVOIDANCE APPROACH

3.1 Introduction

The analysis presented in this section will determine the feasibility of adjacent channel, cosite operation of MSS earth terminals in the vicinity of meteorological satellite receivers. Interference mechanisms to be studied include meteorological receiver gain compression, spurious responses, and intermodulation products. Specifically, the MSS signal level that may be present at the meteorological receiver will be determined and evaluated against the suppression capabilities of two typical meteorological receivers, and the separation distances at which spurious interference responses may be perceptible will be calculated. In addition, the adjacent channel sharing situation considered in Section 2 is revisited (i.e., mobile earth station spurious emissions falling within the meteorological receiver passband). As a final step, the probability of a mobile earth terminal transmitting in the calculated area around a meteorological station where interference may be perceptible is determined and compared with the available sharing criteria.

3.2 Analysis Procedure

3.2.1 Approach

The appropriate parameters from manufacturer's data were assembled and those that could not be obtained were derived. The appropriate spurious responses of concern were determined. Image responses are not a concern since the subject MSS frequencies can not mix with the local oscillator frequency in order to enter the METSAT receiver IF passband). The MSS received signal level was calculated for a variety of off-axis antenna gains, and earth station types (CDA, HRPT, and WEFAX). Separation distances were then calculated that would prevent perceptible desensitization and spurious responses. The probability of mobile earth terminals and meteorological earth stations being within the calculated separation distances was then calculated.

3.2.2 Assumed System Parameters

Table 18 lists the specifications and derived data for Microdyne and Telonics meteorological receivers. Table 19 provides the assumed MSS parameters (since Section 2 determined that spread spectrum MSS operation may not be viable for a frequency avoidance approach to sharing, only a narrowband MSS system is considered). Several assumptions regarding propagation paths and antenna sizes were made to perform this analysis. The transmitting and receiving antennas are assumed to be in the far-field of each other (a safe assumption since theoretical mainbeam far-field is 54 cm for 1675 MHz). Free space loss and co-polar coupling were assumed although it is recognized that additional significant coupling losses can exist for co-located antennas. The interfering signal carriers are assumed to be off-tuned by at least one-half the detector bandwidth from the desired signal carrier.

3.2.3 Gain Compression / Desensitization

Strong, adjacent-channel interfering signals entering a receiver can cause a reduction in the RF gain due to receiver preamplifier and front-end non-linearities. This gain reduction is called desensitization or gain compression and occurs when the interfering signal level exceeds the front-end saturation level. Duff and White[2] provide a model (Equation 1) to calculate the gain reduction due to desensitization that relates the signal-to-noise ratio to the interfering power level, the receiver saturation level, and the rate at which desensitization occurs. Estimates are given for desensitization rate, which is related to the difference between receiver sensitivity and the desired signal level. The model describes a constant signal-to-noise ratio until an interfering signal exceeds the receiver saturation level at which point the signal-to-noise ratio decreases in proportion to the desensitization rate. As the desired signal increases the rate of desensitization decreases.

$$\frac{S'}{N} = \frac{S}{N} - \frac{P_A - P_{SAT}}{R} \qquad 1$$

S'/N = Desensitized signal-to-noise ratio (dB);
S/N = Signal-to-noise ratio without interference (dB);
P_A = Input power of interfering signal (dBm);
P_{SAT} = Receiver saturation level (dBm);
R = Desensitization rate.

3.2.4 Receiver Spurious Response

One possible interference mechanism for receivers situated near high power interfering signals occurs when a non-co-channel MSS signal is down converted to the IF passband of the meteorological receiver. This MSS signal can be misinterpreted as the desired signal (e.g., causing false signal acquisition) or may disrupt receiver automatic gain control (AGC). The frequencies that can produce spurious responses in a receiver can be predicted using Equations 2 and 3 for single- and double- conversion superheterodyne receivers, respectively.

$$f_{SR} = \left| \frac{p f_{LO} \pm f_{IF}}{q} \right| \qquad 2$$

---

[2]William Duff, and Donald White, *A Handbook on EMI Prediction and Analysis Techniques*, Handbook Series on Electromagnetic Compatibility (Gainesville, VA: Interference Control Technologies, 1972), V, p. 4.44.

$$f_{SR} = \frac{p_1 f_{LO_1}}{q_1} \pm \frac{p_2 f_{LO_2} \pm f_{IF_2}}{q_1 q_2} \qquad 3$$

where,
f_{SR} = Spurious response frequency,
p = LO harmonic number,
f_{LO} = LO frequency,
f_{IF} = IF,
q = Interfering signal harmonic number,
subscripts 1&2 = Number of IF stage.

The amplitude of an interfering signal that might cause a spurious response can be calculated using manufacturers specifications for sensitivity and spurious rejection and Equation 4.

$$P_{SR} = P(f_{OR}) + I\log(p) + J \qquad 4$$

where,
P_{SR} = Power level required of interfering signal that may cause a spurious response (dBm),
$P(f_{OR})$ = Receiver sensitivity (dBm),
I = Slope of IF filter,
p = Local oscillator harmonic number,
J = Intercept of response function.

3.2.5 Receiver Response to MSS Spurious Emissions

Another potential interference mechanism originates from the spurious emission of the MSS transmitter that falls within the receiver passband. The spurious emission levels are given in "Suppression of Spurious Emissions From Mobile Earth Stations in the 1626.5-1660.5 MHz Band" (US WP 8D/10 (Rev. 10) and are listed in Table 11 (narrowband MSS system).

3.2.6 Third-Order Intermodulation Products

Third-order intermodulation products generated in a meteorological receiver by two mobile earth stations are unlikely to occur. Both interfering signals would have to be of sufficient amplitude and at certain specific relative frequencies in order to cause a potentially interfering intermodulation product.

3.3 Methodology for Addressing Probability of Interference

Once the separation distances required to protect meteorological earth stations are calculated for all potential interference interactions, the probability that a mobile earth station may be transmitting within an area around a meteorological earth station were determined. This area is based on the largest of the calculated separation distances and is shown in Figure 1.

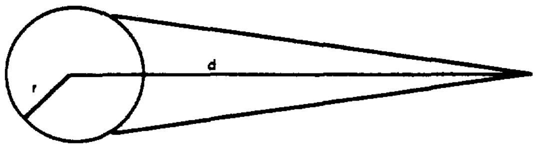

Figure 1 - Area About Meteorological Earth Station

The probability of potentially perceptible interference is calculated according to Equation 5. The MSS satellite antenna coverage area was determined from the antenna contours provided in the coordination data for AMSC's current system (AR11/C/1106), using the 4 dB contour to define the edge of coverage.

$$P = \frac{N}{A_b} \times DF \times A_{ac} \qquad 5$$

where,

P = Probability of perceptible interference,
N = Number of MSS channels in antenna beam,
A_b = MSS satellite beam coverage area (4 dB contour) (km^2),
A_{ac} = Area about meteorological earth station in which a mobile earth station may cause perceptible interference (km^2),
DF = Transmission duty factor in an assigned (active) MSS uplink channel.

3.4 Separation Distances for the Prevention of Interference

3.4.1 Desensitization

Table 20 shows the separation distances between a meteorological earth station and the MSS earth terminal that result in an MSS signal level equal to the receiver saturation level with the receiver operating at maximum sensitivity (e.g., during signal acquisition). The distances range from 2 m to 56 m, with the closest distances being associated with CDA stations and the farthest distances being associated with the WEFAX stations. Table 21 illustrates that perceptible interference could occur through desensitization with higher than the assumed MSS interfering signal levels.

3.4.2 Receiver Spurious Responses

The distance from the meteorological receiver where the MSS signal level at the receiver IF is at the same level as the receiver sensitivity was calculated for a variety of conditions. The desired received signal level was assumed to be the same as the receiver sensitivity (this is valid for meteorological receivers acquiring the desired signals at low elevation angles). Tables 22 and 23 tabulate the conditions and the results of separation distance calculations for receiver generated spurious responses assuming a 60 dB level of receiver spurious rejection. The off-tuning is assumed to be sufficient to achieve the 60 dB spurious rejection of the receiver. Separation distances were calculated for three types of meteorological earth stations (CDA, HRPT, and WEFAX) to provide a range of distances that result from different sensitivities (reflecting the different earth station bandwidths and antenna diameters). The receiver antenna gain reflects the discrimination of the receiver antenna when the interferer is in the mainbeam azimuth (i.e., at off-axis angles of 5° and 10° due to meteorological receiver antenna elevation), and in the backlobe of the receiver antenna.

3.4.3 Receiver Response to MSS Spurious Emission

Table 24 tabulates the results of separation distance calculations for receiver responses due to an MSS spurious emission level of -63 dBc following the spurious emission level given in US WP 8D/10 (Rev 10). Separation distances were calculated for three types of meteorological earth stations, CDA, HRPT, and WEFAX, in order to provide a range of distances that result from different permissible levels of interference and antenna diameters. The receiver antenna gain reflects the discrimination of the antenna when the interferer is in the mainbeam azimuth (at off-axis angles of 5° and 10° due to the elevation of the meteorological receiver antenna) and in the backlobe of the receiver antenna. The signal level at the receiver antenna was compared to the permissible level of interference given in Table 25. These levels were taken from the sharing and coordination criteria given in ITU-R Document 7/87-E for the LEO systems and the criteria for the WEFAX station was calculated using the method of ITU-R Document 7/83.

3.5 Probability of Exceeding the Interference Threshold

Table 26 lists the probabilities of a MSS earth terminal being within the areas of potentially perceptible interference, as calculated using the above distances and the method of Section 3.3. These results indicate a lower probability of interference than is generally considered to be permissible in the meteorological-satellite service (e.g., 0.005% of the time, as in Document ITU-R 7/87).

4.0 CONCLUSIONS

MSS uplinks and meteorological systems can share the 1675-1710 MHz band using frequency avoidance, time sharing and geographic separation techniques. Specifically, it was shown in Section 3 that interference would be below the permissible level if mobile earth stations transmission frequencies are offset from meteorological system frequencies, and Table 9 indicates that numerous narrowband MSS channels could be available on that basis. The review of representative meteorological systems (Section 2.1.3) indicates that certain geostationary METSAT downlinks and all LEO METSAT downlinks and METAIDS systems are operated part-time in North America, which may enable time-shared MSS access to additional frequencies. Substantial distance separations are required for concurrent co-channel operation of mobile earth stations and meteorological receivers and locations of meteorological receivers are not known in most cases; thus, this sharing approach has very limited feasibility. Co-channel sharing on the basis of geographic separation may be feasible only on frequencies used only for transmissions to METSAT CDA stations and perhaps for METAIDS stations (i.e., stations with known locations), and then only if the mobile earth station is known to be located beyond interfering range to these stations.

REFERENCES

1. Petition of AMSC, Attachment 1, June 3, 1991.

2. IFRB Advanced Publication data, Weekly Circular, Special Section AR11/C/1106, September 22, 1987.

3. Report of the MSS Above 1 GHz Negotiated Rulemaking Committee, April 6, 1993.

4. FCC Form 493 filed by AMSC Attachment A of Exhibit 1, Spring 1993.

5. Part 25.202 of the Federal Code of Regulations, October 1992.

6. Interference Criteria for Space-to-Earth Data Transmission Systems Operating in the Earth Exploration Satellite and Meteorological-Satellite Services Using Satellites in Low Earth Orbit, USSG 7C/8 (Rev. 1), January 13, 1993.

7. Feasibility of Frequency Sharing Between a Geostationary Meteorological Satellite System and the Meteorological Aids Service in the region of 400 MHz and the Lower Part of Band 9 (1 to 3 GHz), CCIR Report 541, Vol 2, 1990.

8. Flynn, Francis, Spectrum Resource Assessment in the 1660-1710 MHz Band, NTIA, NTIA-TR-81-80, September 1981.

Table 1 - Current International Allocations

Frequency	Region 1	Region 2	Region 3
1675- 1690 MHz	METEOROLOGICAL AIDS FIXED METEOROLOGICAL SATELLITE (space-to-earth) MOBILE (except aeronautical mobile) 722	METEOROLOGICAL AIDS FIXED METEOROLOGICAL SATELLITE (space-to-earth) MOBILE (except aeronautical mobile) MOBILE SATELLITE (earth-to-space) 722, 735A	METEOROLOGICAL AIDS FIXED METEOROLOGICAL SATELLITE (space-to-earth) MOBILE (except aeronautical mobile) 722
1690- 1700 MHz	METEOROLOGICAL AIDS METEOROLOGICAL SATELLITE (space-to-earth) Mobile (except aeronautical mobile) Fixed 671, 722	METEOROLOGICAL AIDS METEOROLOGICAL SATELLITE (space-to-earth) MOBILE SATELLITE (earth-to-space) 671, 722, 735A	METEOROLOGICAL AIDS METEOROLOGICAL SATELLITE (space-to-earth) 671, 722
1700- 1710 MHz	FIXED METEOROLOGICAL SATELLITE (space-to-earth) MOBILE (except aeronautical mobile) 671, 722	FIXED METEOROLOGICAL SATELLITE (space-to-earth) MOBILE (except aeronautical mobile) MOBILE SATELLITE (earth-to-space) 671, 722	FIXED METEOROLOGICAL SATELLITE (space-to-earth) MOBILE (except aeronautical mobile) 671, 722

RR 671 - Earth exploration-satellite applications, other than the meteorological-satellite service, may also be used in the bands 460-470 MHz and 1670-1690 MHz for space-to-Earth transmissions subject to not causing harmful interference to stations operating in accordance with the Table.

RR 722 - In the bands 1400-1727 MHz, 101-120 GHz and 197-220 GHz, passive research is being conducted by some countries in a program for the search for intentional emissions of extra-terrestrial origin.

RR 735A - In the band 1675-1710 MHz, stations in the mobile-satellite service shall not cause harmful interference to, nor constrain the development of, the meteorological-satellite and meteorological aids services (see Resolution 213 (WARC-92)) and the use of this band shall be subject to the provisions of Resolution 46 (WARC-92).

Table 2 - Stations in the IFL Organized By Station Type

STATION TYPE	ITU CLASS OF STATION.	QUANTITY OF ASSIGNMENTS
Fixed	FX	246
Meteorological Satellite Earth Station	TM	444
Meteorological Satellite Space Station	EM	190
Space Telemetering Earth Station	TR	59
Space Telemetering Space Station	ER	48
	SM	27
Space Tracking Earth Station	TK	49
Space Tracking Space Station	EK	101
Radio Astronomy Station	RA	24
Earth Exploration Satellite Earth Station	TW	17
Earth Exploration Satellite Space Station	EW	24
Land Mobile Station	ML	31
Space Research Earth Station	TH	32
Space Research Space Station	EH	8

Table 3 - Stations in the IFL Organized By Country

COUNTRY	ITU ABBREVIATION	QUANTITY OF ASSIGNMENTS	REGION
Czechoslovak National Republic	TCH	10	Europe
Germany	D	109	Europe
	ORB	302	
Sudan	SDN	4	Africa
Belgium	BEL	20	Europe
Belize	BLZ	3	Central America
India	IND	12	Asia
Iceland	ISL	4	Europe
New Zealand	NZL	2	Asia
Poland	POL	2	Europe
United States	USA	116	No America
Hawaii	HWA	8	No. America
Switzerland	SUI	41	Europe
Byelorussian	BLR	4	Europe
China	CHN	45	Asia
Ukrainian Soviet Socialist Rep.	UKR	4	Europe
Union of Soviet Socialist Rep.	URS	28	Europe
Singapore	SNG	26	Asia
Canary Islands	CNR	14	Europe
Spain	E	210	Europe
Sweden	S	30	Europe
Japan	J	95	Asia
Alaska	ALS	25	No. America
	SPA	69	
Canada	CAN	6	No. America
Pakistan	PAK	4	Asia
Finland	FNL	5	Europe
Saudi Arabia	ARS	12	Africa
Netherlands Antilles	ATN	4	Europe
France	F	4	Europe
Sultanate of Oman	OMA	4	Africa
Argentine Republic	ARG	8	So. America
Netherlands	HOL	2	Europe
Mexico	MEX	4	No. America
Cuba	CUB	2	No. America
Italy	I	62	Europe

Table 4 - Representative US Meteorological Satellite Systems

Metsat System	NOAA K-N LEO CDA (current)	NOAA K-N LEO HRPT (current)	NOAA OPQ LEO HRPT (future)	NOAA GOES Links (3) (current)
Satellite Output Power	8 dBW (1)	8 dBW (1)	12.6 dBW	12.2 dBW EIRP
Satellite Antenna Pattern	Conical	Conical	Conical	Conical
Satellite Antenna Gain	2 dBi (1)	2 dBi (1)	2.1 dBi (1)	15.7 dBi (2)
Orbit Parameters: Inclination Altitude	2 - 3 satellites 98.8° 844 km	2 - 3 satellites 98.8° 844 km	1 US, 98.8°, 844 km (4)	Three Satellites in Geostationary Orbit
Emission or Reference Bandwidth	5.334 MHz (1)	2.668 MHz (1)	2.5 MHz	CDA Weather data - 25 MHz DRGS stretched data - 3.5 MHz FC fax data- 26 kHz
Modulation	PCM/BPSK	BPSK	UQPSK	BPSK, FM
Receiver Antenna Gain	46.8 dBi	29.8 dBi	29.8	CDA: 47.6 dBi DRGS: 37.5 dBi FC: 30 dBi
Noise Bandwidth	2.667 MHz	1.33 MHz	1.75 MHz	CDA: 8.2 and 25 MHz DRGS: 3.5 MHz FC: 50 kHz
Interference Criteria Permissible Interference Power	-128 dBW per 5.334 MHz	-141 dBW per 2.668 MHz	-141 dBW per 2.668 MHz	CDA: -144.6 dBW DRGS:- 148.4 dBW FC: -159.9 dBW
Permissible Interference				10 dB C/I
Receiver System Noise Temperature	320 K (1)	370 K	370 K	CDA: 100 K DRGS: 300 K FC: 1500 K
Earth Station Locations	Gilmore Creek, Alaska, Wallops Island, Virginia	Worldwide	Worldwide	ITU Region 2 (for CDA receiver sites, see NOAA KLMN sites)

Notes:

CDA - Command Data Acquisition station
DRGS - Direct Readout Ground Station
FC - Forecast Center (WEFAX broadcast)

1. Satellite antenna gain/EIRP is specified towards the Earth horizon, where maximum values are directed; gain and EIRP are at their minimum values toward Nadir.
2. Satellite uses Earth coverage antenna; indicated gain is toward CONUS.
3. Only representative current GOES links are listed. Ranging, Data Collection Platform (DCP), and telemetry links are not included
4. A European satellite also will serve North America using NOAA OPQ parameters.

Table 5 - Representative Foreign Meteorological Satellite Systems

System	METEOSAT (Europe)	GMS (Japan)
Service	Metsat	Metsat
Satellite Output Power	DATTS - -7.5 dBW DATTS/PDUS - 7.3 dBW DATTS/SDUS - 7.3 dBW	VISSR - 11 dBW CDA/MDUS - 11 dBW CDA/SDUS - 11 dBW
Satellite Antenna Gain	DATTS - 14 dBi DATTS/PDUS - 14 dBi DATTS/SDUS - 14 dBi	VISSR - 48 dBi CDA/MDUS - 35 dBi CDA/SDUS - 30 dBi
Orbit Parameters: Inclination Altitude	Geostationary (1)	Geostationary (1)
Bandwidth	DATTS - 660 kHz DATTS/PDUS - 660 kHz DATTS/SDUS - 26 kHz	VISSR - 20 MHz CDA/MDUS - 1 MHz CDA/SDUS - 260 kHz
Modulation	F9, F4	VISSR - G1D CDA/MDUS - F3C CDA/SDUS -F3C
Receiver Antenna Gain	CDA/DATTS - 45 dBi PDUS -35 dBi SDUS - 30 dBi	VISSR - 48 dBi CDA/MDUS - 35 dBi CDA/SDUS - 30 dBi
Receiver System Noise Bandwidth	CDA/DATTS - 25 kHz PDUS -1000 kHz SDUS - 50 kHz	VISSR - 1 MHz CDA/MDUS - 260 kHz CDA/SDUS - 1 MHz
Temperature	CDA/DATTS - 115 K PDUS - 250 K SDUS - 560 K	VISSR - 300 K CDA/MDUS - 500 K CDA/SDUS - 600 K
Earth Station Locations	(2)	(2)

DATTS - Data acquisition telecommand and tracking station
PDUS - Primary data user station
SDUS - Secondary data user station

1. Located at longitudes for service to areas indicated in first row, except when on loan to another administration.
2. If relocated to serve North America, US receiver sites will be the same as for GOES (Table 4).

Table 6 - Representative Meteorological Aid Systems

Nature of Parameter	Maximum Value	Minimum Value
Radiosonde Output Power	0 dBW (peak)	-6 dBW
Radiosonde Antenna Pattern	1/2 wave dipole	
Radiosonde Antenna Gain	2 dBi	0 dBi
Flight Parameters:	4 scheduled flights per day, 2 km altitude, 700 km range (1)	2 scheduled flights per day (1)
Emission Bandwidth	15 kHz (non-ranging) 400 kHz (ranging)[2]	15 kHz (non-ranging) 400 kHz (ranging)[2]
Modulation	Interrupted CW / FM	Interrupted CW / FM
Receiver Antenna Pattern	Parabolic w/ conical scan feed	Parabolic w/ conical scan feed
Receiver Antenna Gain	28 dBi	28 dBi
Noise Bandwidth	1.5 MHz	1.5 MHz
Permissible Interference Power	PFD of -133 dBW/1.5 MHz	PFD of -133 dBW/1.5 MHz
Interference Criteria, I/N		
Receiver System Noise Temperature	2900 K	2900 K
Earth Station Locations	Nation-wide network	Nation-wide network

1. Flights typically made at 0000, 0600, 1200, and 1800 hours UTC (0000 and 1200 hours UTC in cases of two flights per day).

Table 7 - Current Usage of the 1670-1710 MHz Band By
United States Meteorological Satellites

Geostationary Meteorological-Satellites Serving Region 2 and
Atlantic and Pacific Ocean Areas From West Atlantic and
East Pacific Orbital Locations
(GOES)

Type of Data Link	Center Frequency	3 dB Bandwidth
VAS Data	1681.600 MHz	23.2 MHz
Extended VAS WEFAX Ranging	1688.100 MHz	8.2 MHz
Telemetry	1694.000 MHz	200 kHz
Data Collection Platform (DCP) Relay	1694.500 MHz	400 kHz

Low Earth Orbit Meteorological-Satellites (Two)
Providing Worldwide Service From Near-Polar
Orbits at About 800 km Altitude
(NOAA KLMN)

Frequencies	Type of Data Link	Bandwidth
2 per satellite: 1698.0 MHz or 1707 MHz (HRPT) and 1702.5 MHz (CDA) (1)	One Command and Data Acquisition (CDA) Link per Satellite Over North America (2)	5.334 MHz
	One Full Time High Resolution Picture Transmission (HRPT) Link per Satellite (3)	2.668 MHz

(1) Functions normally accommodated on the specified carrier frequencies are listed. However, in failure modes, CDA and HRPT may be accommodated on any of the three frequencies.
(2) One frequency is used for all satellites under normal operations.
(3) Frequencies are not normally reused, but only one satellite is visible at the same time.

Table 8 - Planned Usage of the 1670-1710 MHz Band By
United States Meteorological Satellites

Geostationary Meteorological-Satellites Serving Region 2 and
Atlantic and Pacific Ocean Areas From West Atlantic and
East Pacific Orbital Locations
(GOES NEXT)

Type of Data Link	Center Frequency	3 dB Bandwidth
Raw Sensor Data	1676.000 MHz	5.0 MHz
Multi-Use Data	1681.478 MHz	500 kHz
Processed Data	1685.700 MHz	5.0 MHz
WEFAX	1691.000 MHz	1.0 MHz
Telemetry	1694.000 MHz	20 kHz
DCP Pilot	1694.450 MHz	400 kHz
DCP Relay Band 1	1694.500 MHz	400 kHz
DCP Relay Band 2	1694.800 MHz	400 kHz

Low Earth Orbit Meteorological-Satellites (One US & One European)
Providing Worldwide Service From Near-Polar Orbits
at About 800 km Altitude
(NOAA OPQ)

Frequencies	Type of Data Link	Bandwidth
1 per satellite: near 1702 MHz and near 1707 MHz	Advanced HRPT (2 ch. Unbalanced QPSK)	2.5 MHz

Table 9 - Tabulation of Bandwidth Not Occupied By Current and Planned U.S. Meteorological Spacecraft*

Current GOES and NOAA Series Satellites

Lower Guardband Edge	Upper Guardband Edge	Unoccupied Bandwidth
1693.2 MHz	1693.9 MHz	0.6 MHz
1694.1 MHz	1694.3 MHz	0.2 MHz
Various locations between 1694.7 MHz and 1710 MHz depending on which LEO satellite is serving the US and whether any NOAA KLMN transmitters have failed		7.3 MHz during CDA downlink operations and 15.3 MHz at other times
TOTAL		8.1 - 16.1 MHz

Future GOES and NOAA Series Satellites

Lower Guardband Edge	Upper Guardband Edge	Unoccupied Bandwidth
1670.0 MHz	1671.0 MHz	1.0 MHz
1678.5 MHz	1681.23 MHz	2.73 MHz
1681.73 MHz	1683.2 MHz	1.47 MHz
1688.2 MHz	1690.5 MHz	2.3 MHz
1691.5 MHz	1693.9 MHz	2.4 MHz
1694.1 MHz	1694.25 MHz	0.15 MHz
1695.0 MHz	1700.75 MHz	5.75 MHz
1703.25 MHz	1710.0 MHz	6.75 MHz
Total		22.55 MHz

*NOTE: Current METAIDS systems typically operate in the 1670-1680 MHz band. None of the spectrum that is "unoccupied" by current METSAT systems falls within this METAIDS band. Only 2.5 MHz of the 22.55 MHz that may be "unoccupied" by future METSAT systems falls in this METAIDS band. Thus, for the most part, frequency avoidance with respect to METSAT systems also yields frequency voidance with METAIDS systems.

Table 10 - Assumed MSS System Parameters for General Analysis

PARAMETER	Narrowband	Spread Spectrum
Met EIRP	15 dBW/4 kHz	-15 dBW/carrier
Met Antenna Pattern	omni	omni
Met Antenna Gain	9 dBi	5 dBi
Emission 3 dB Bandwidth	2.97 kHz	1.25 MHz
Modulation	QPSK	PSK
Noise Bandwidth	4.22 kHz	1.25 MHz
Met Receiver Noise Temperature	290 K	290 K
Interference Criteria, I/N=-5 dB	-209 dBW/Hz	-209 dBW/Hz
Satellite Antenna Pattern	Spot beam	Spot beam
Satellite Antenna Gain	32 dBi	32 dBi
Satellite Antenna Discrimination: toward edge of coverage toward edge of earth	 4 dB 20 dB	 4 dB 20 dB
Orbit Altitude	35880 km	35880 km
SatelliteTransmitter Output Power	3.5 dBW	3.5 dBW
Satellite Temperature	633 K	633 K
Interference Criteria, I/N=-5 dB	-205.6 dBW/Hz	-205.6 dBW/Hz

Table 11 - Assumed MSS Emission Spectral Density

Narrowband Emission Spectral Density		Spread Spectrum Emission Spectral Density	
Frequency from Center, f/3375 Hz	Power Density, dB Below Carrier	Frequency from Center, f/1.25 MHz	Power Density, dB Below Carrier
0 - .6	0	0 - .5	0 dB
.6 - 1.0	linear slope	.5 - 1.0	25 dB
1.0 - 1.6	-35	1.0 - 2.5	35 dB
1.6 - 2.0	linear slope	> 2.5	43 dB + $10\log P_{transmitter}$ $P_{transmitter}$ = transmitter power in watts
2.0 - 2.6	-45		
2.6 - 3.0	linear slope		
> 3.0	-50		

Table 12 - Summary of Analysis Input Parameters and Results MSS Narrowband Interference to Meteorological Receivers

Meteorological Receiver and Associated Type of Satellite	Meteorol. Receiver Antenna Diameter	Minimum Meteorological Receiver Antenna Off-axis Angle (1)	Mobile Earth Station EIRP (dBW) (2)	Meteorol. Receiver Antenna Height (m)	Mobile Earth Sta. Antenna Height (km), (3)	Permissible Interference (dBW) (4)	Co-channel Separation Distance (km) (5)		Adjacent Channel Separation Distance (km) (5)	
							Minimum	Maximum	Minimum	Maximum
MSS NB to Metsat GOES Forecast Center	2.3 m (2.44 m)	20°	15 dBW	2 m	2 m	-159.9 dBW	31.8	24.3	6.5	2.2
MSS NB to Metsat GOES WB	17.4 m	20°	15 dBW	10 m	2m	-144.6 dBW	24.1	16.9	2.1	0.4
MSS NB to Metsat NOAA CDA	15.9 m (25.9 m)	5°	15 dBW	15m	2 m	-121 dBW/ 5.334 MHz	20.9	4.6	1.0	0
MSS NB to Metsat NOAA (sm. sta.)	2.25 m (2.44 m)	5°	15 dBW	2 m	2 m	-139 dBW/ 2.668 MHz	27.2	9.3	3.6	0 km
MSS NB to Metsat NOAA OPQ	2.25 m (2.44 m)	5°	15 dBW	2 m	2 m	-139 dBW/ 2.668 MHz	27.2km	9.3 km	3.6 km	0 km
MSS NB to Metsat Meteosat (SDUS)	2.3 m	20°	15 dBW	2 m	2 m	-159.1 dBW	31.1 km	23.6 km	6 km	1.9 km
MSS NB to Metsat Meteosat (CDA/DATTS)	12.9 m	20°	15 dBW	10 m	2 m	-169 dBW	44.8 km	37.0 km	17 km	10.4 km
MSS NB to Metsat GMS CDA	2.3 m	20°	15 dBW	3 m	2 m	-145.8 dBW	23.4 km	16.3km	0 km	0 km
MSS NB to Metsat GMS (VISSR)	18.3 m	20°	15 dBW	10 m	2 m	-137 dBW	18.3 km	11.5 km	km	0 km
MSS NB to MetAids	1.8 m	5°	15 dBW	3 m	2 m	-133 dBW	26.0 km	8.3 km	3 km	0 km

1. The minimum METSAT earth station off-axis angle occurs in the azimuth containing the earth station main beam. In the case of LEO spacecraft, only the minimum earth station main beam elevation angle was assumed, although SG 12 Recommendation allows use of antenna pointing statistics that would yield a lower equivalent antenna gain towards the horizon (i.e., small separation distance).
2. The mobile earth station EIRP of 15 dBW is assumed to be radiated toward the horizon in all azimuths. The actual EIRP values may be somewhat lower, depending on location relative to the satellite (e.g., for mast antennas and other mobile antenna types that track the satellite). For adjacent channel calculations the MSS EIRP was assumed to be -20 dBW.
3. Truck installation assumed.

Table 13- Summary of Analysis Input Parameters and Results for MSS Spread Spectrum Interference to Metsat

Analysis Type	Metsat E/S Antenna Diameter	Minimum Metsat E/S Antenna Off-axis Angle (1)	Mobile E/S EIRP(2)	Metsat E/S Antenna Height (3)	MSS Antenna Height (4)	Permissible Interference	Co-channel Separation Distance Minimum	48°	Adjacent Channel Separation Distance Minimum	48°
MSS NB to Metsat GOES Forecast Center	2.44 m	20°	15 dBW/1.25 MHz	2 m	2 m	-159.9 dBW	18.7 km	11.9 km	6.5 km	2.2 km
MSS NB to Metsat GOES WB	17.4 m	20°	15 dBW/1.25 MHz	10 m	2m	-144.6 dBW	24.1 km	16.9 km	2.1 km	0.4 km
MSS NB to Metsat NOAA CDA	25.9 m	5°	15 dBW/1.25 MHz	15m	2 m	-121 dBW/ 5.334 MHz	20.9 km	4.6 km	1 km	0 km
MSS NB to Metsat NOAA (sm. sta.)	2.25 m (2.44 m)	5°	15 dBW/1.25 MHz	2 m	2 m	-139 dBW/ 2.668 MHz	27.2 km	9.3 km	3.6 km	0 km
MSS NB to Metsat NOAA OPQ	2.44 m	5°	15 dBW/1.25 MHz	2 m	2 m	-139 dBW/ 2.668 MHz	27.2 km	9.3 km	3.6 km	0 km
MSS NB to Metsat Meteosat (SDUS)	2.3 m	20°	15 dBW/1.25 MHz	2 m	2 m	-159.1 dBW	20.2 km	13.3 km	6 km	1.9 km
MSS NB to Metsat Meteosat (CDA/DATTS)	12.9 m	20°	15 dBW/1.25 MHz	10 m	2 m	-169 dBW	30.9 km	23.5 km	17 km	10.4 km
MSS NB to Metsat GMS CDA	2.3 m	20°	15 dBW/1.25 MHz	3 m	2 m	-145.8 dBW	22.7 km	15.6 km	0 km	0 km
MSS NB to Metsat GMS (VISSR)	18.3 m	20°	15 dBW/1.25 MHz	10 m	2 m	-137 dBW	17.5 km	10.8 km	0km	0 km
MSS NB to MetAids	1.8 m	5°	15 dBW/1.25 MHz	3 m	2 m	-133 dBW	26 km	8.3 km	3 km	0 km

1. The minimum METSAT earth station off-axis angle occurs in the azimuth containing the earth station main beam. In the case of LEO spacecraft, only the minimum earth station main beam elevation angle was assumed, although SG 12 Recommendation allows use of antenna pointing statistics that would yield a lower equivalent antenna gain towards the horizon (i.e., small separation distance).
2. The mobile earth station EIRP of 15 dBW is assumed to be radiated toward the horizon in all azimuths. The actual EIRP values may be somewhat lower, depending on location relative to the satellite (e.g., for mast antennas and other mobile antenna types that track the satellite). For adjacent channel calculations the MSS EIRP was assumed to be -20 dBW. An on-tune rejection factor was applied where the spread spectrum signal was wider than the receiver bandwidth (i.e., GOES FC, Meteosat DATTS and SDUS, and GMS VISSR and SDUS).